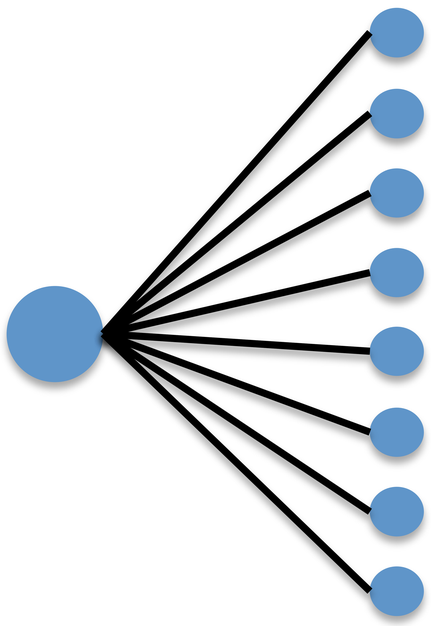
C3: Cutting Tail Latency in Cloud Data Stores via Adaptive Replica Selection

Lalith Suresh
(TU Berlin)

with Marco Canini (UCL), Stefan Schmid, Anja Feldmann (TU Berlin)

Tail-latency matters

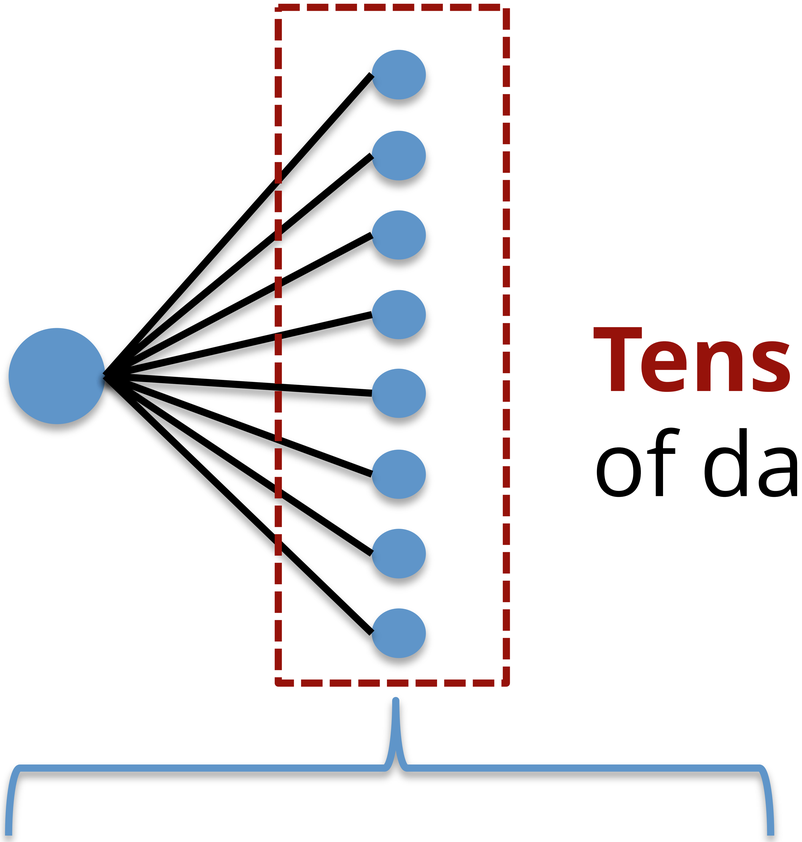
One
User Request



Tens to Thousands
of data accesses

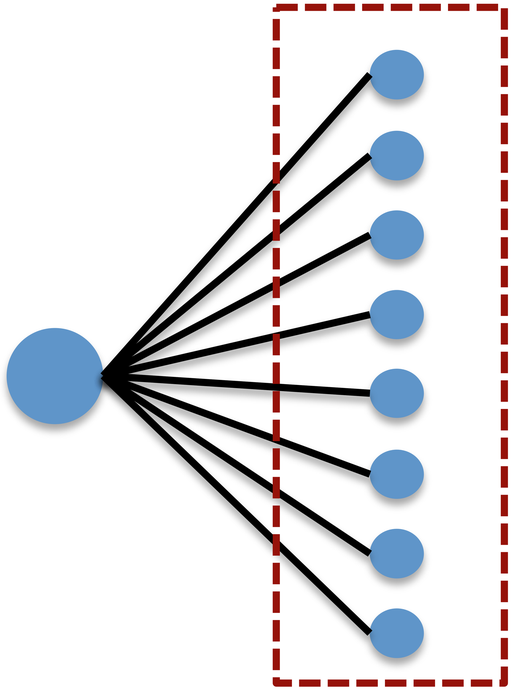
Tail-latency matters

One
User Request

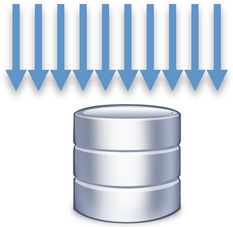


Tens to Thousands
of data accesses

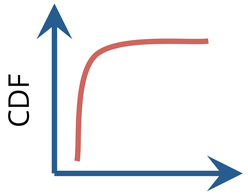
For 100 leaf servers, 99th percentile latency will reflect in 63% of user requests!



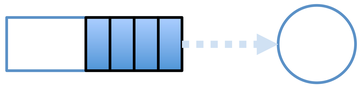
Server performance fluctuations are the norm



Resource contention



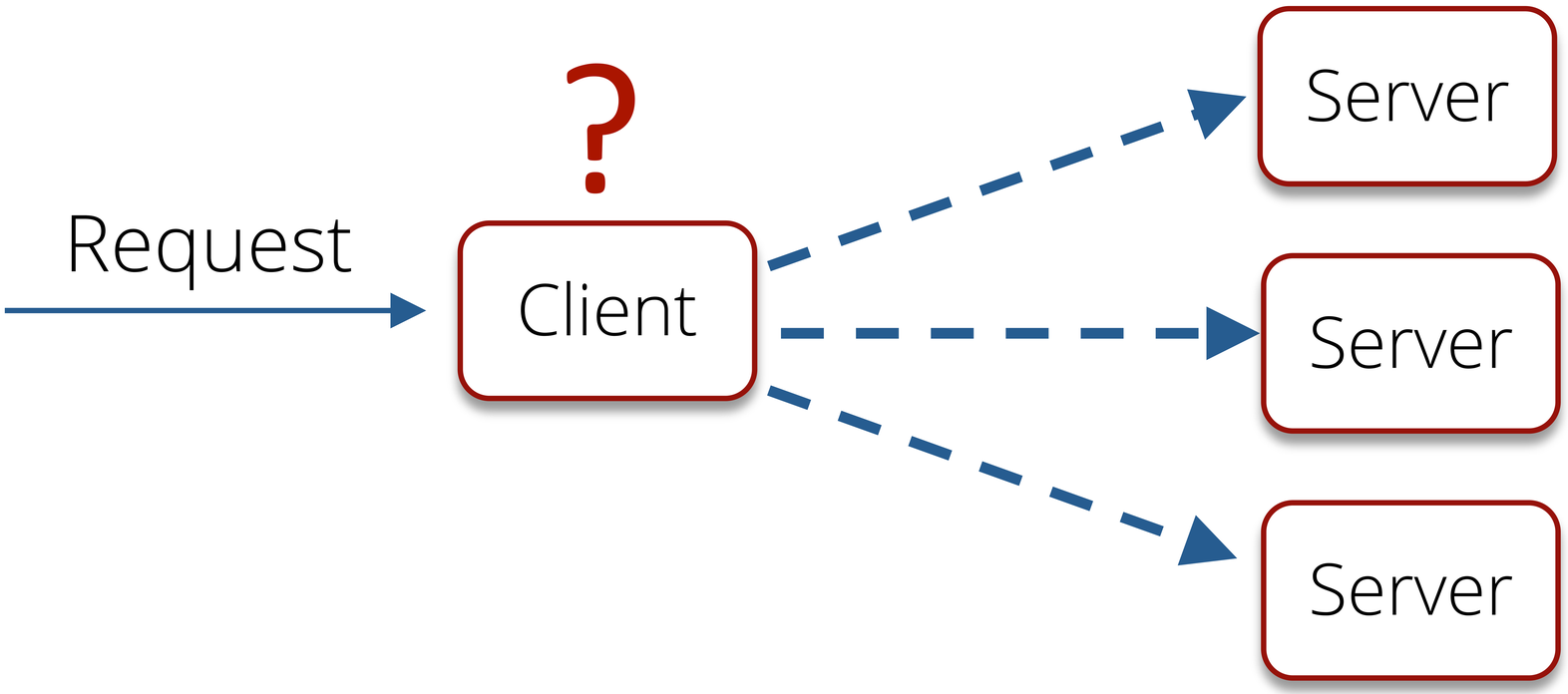
Skewed access patterns



Queueing delays

Background activities

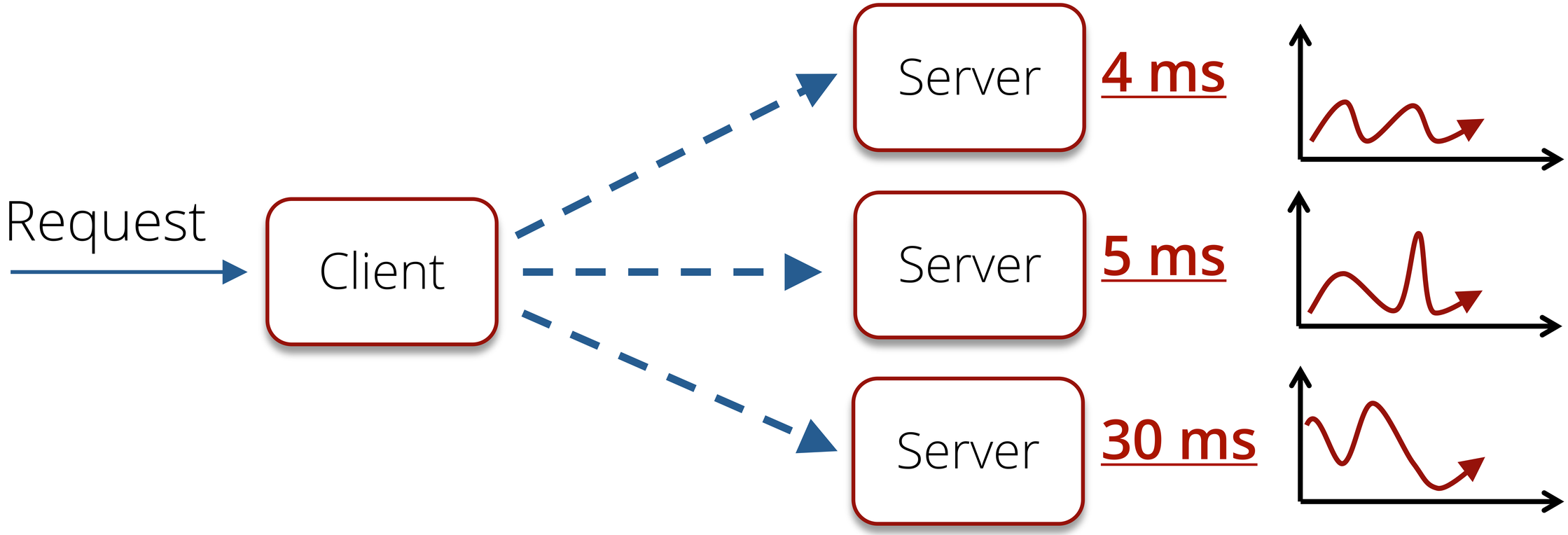
Effectiveness of replica selection in reducing tail latency?



Replica Selection Challenges

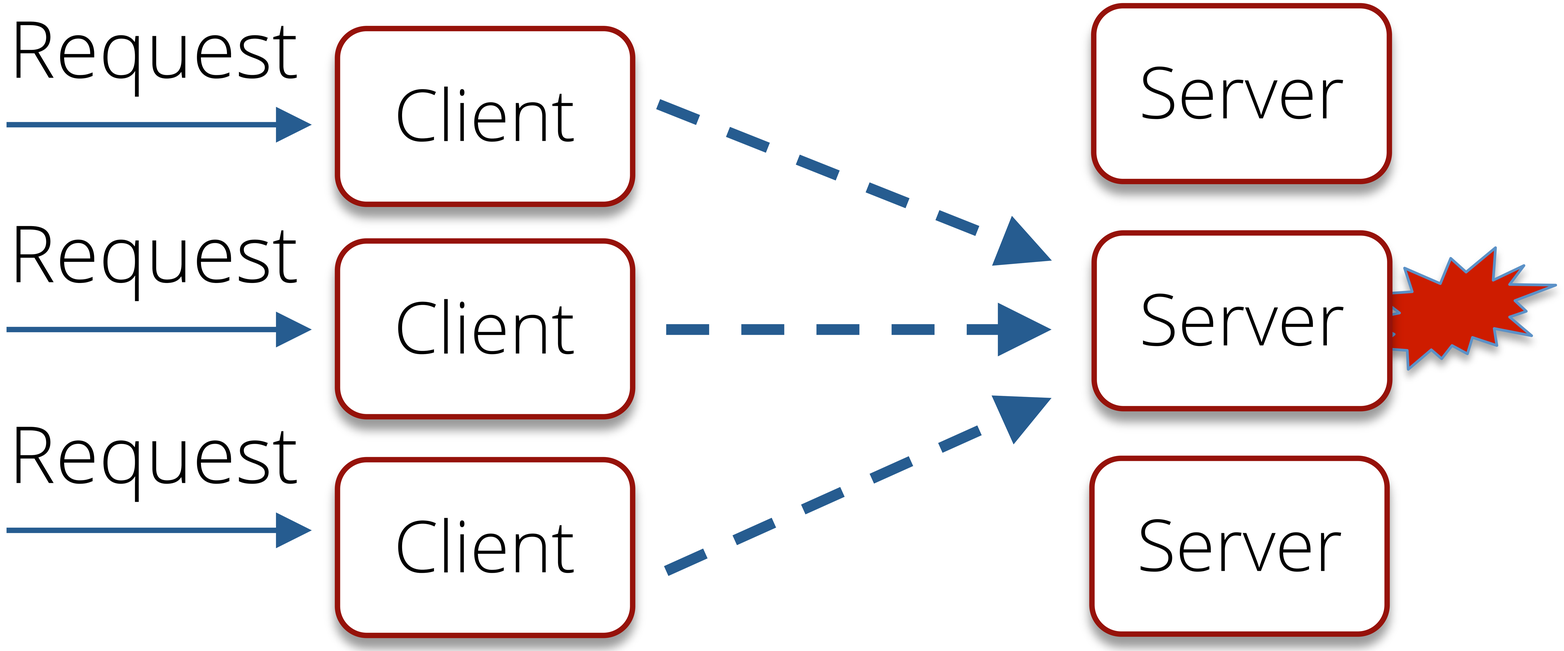
Replica Selection Challenges

- Service-time variations



Replica Selection Challenges

- Herd behavior and load oscillations



Impact of Replica Selection in Practice?

Cassandra

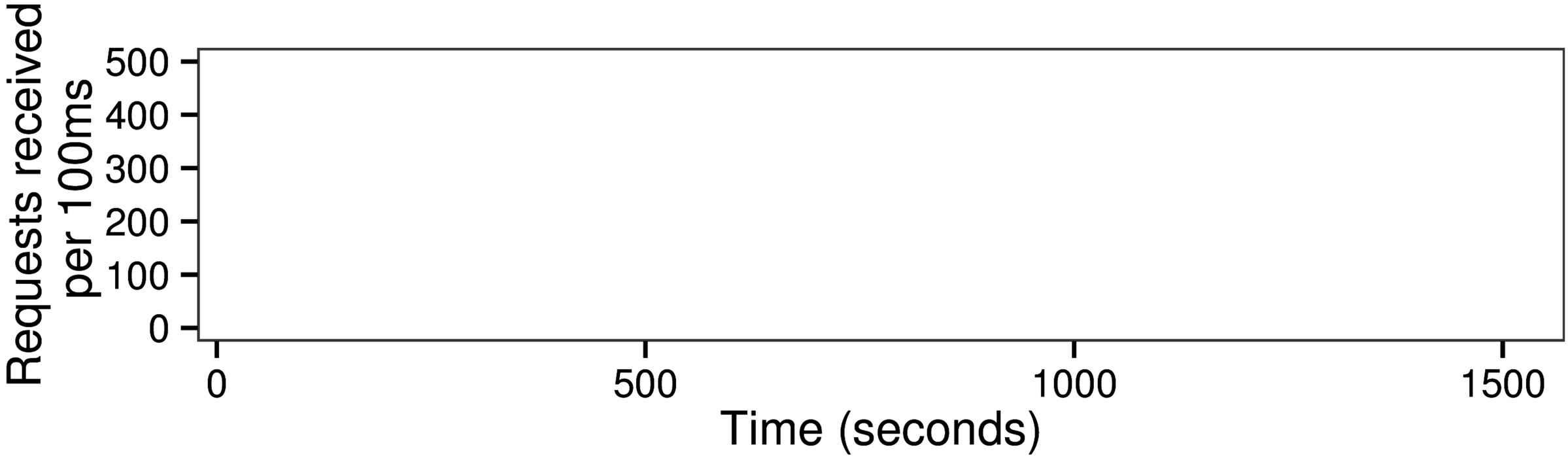
Dynamic Snitching

Uses history of read latencies and I/O load for replica selection

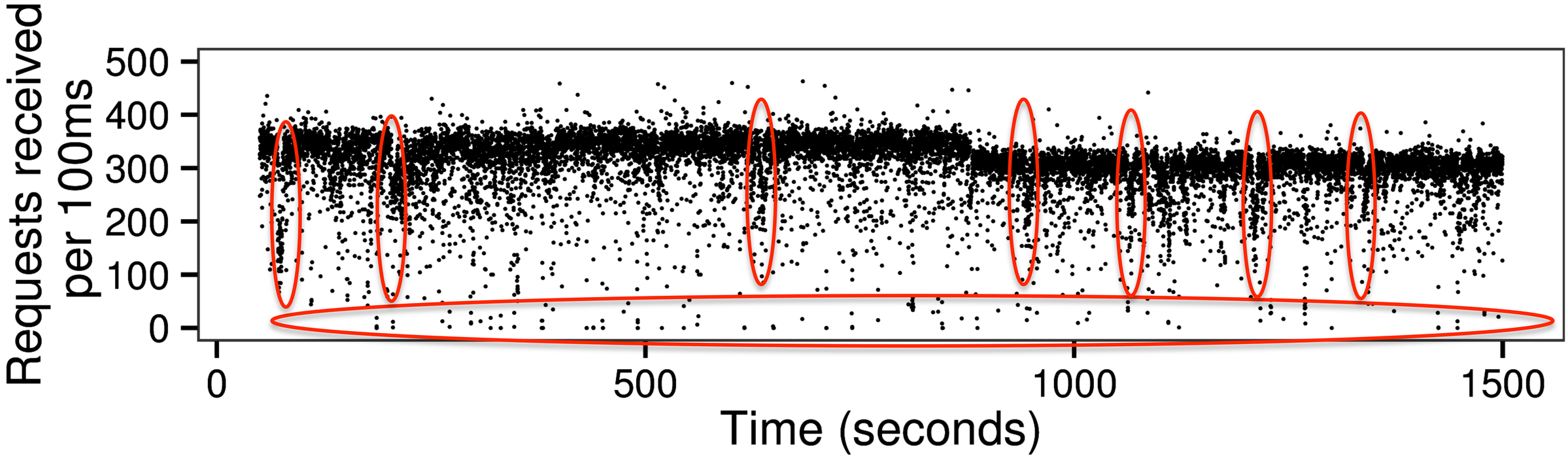
Experimental Setup

- Cassandra cluster on Amazon EC2
- 15 nodes, m1.xlarge instances
- Read-heavy workload with YCSB (120 threads)
- 500M 1KB records (larger than memory)
- Zipfian key access pattern

Cassandra Load Profile

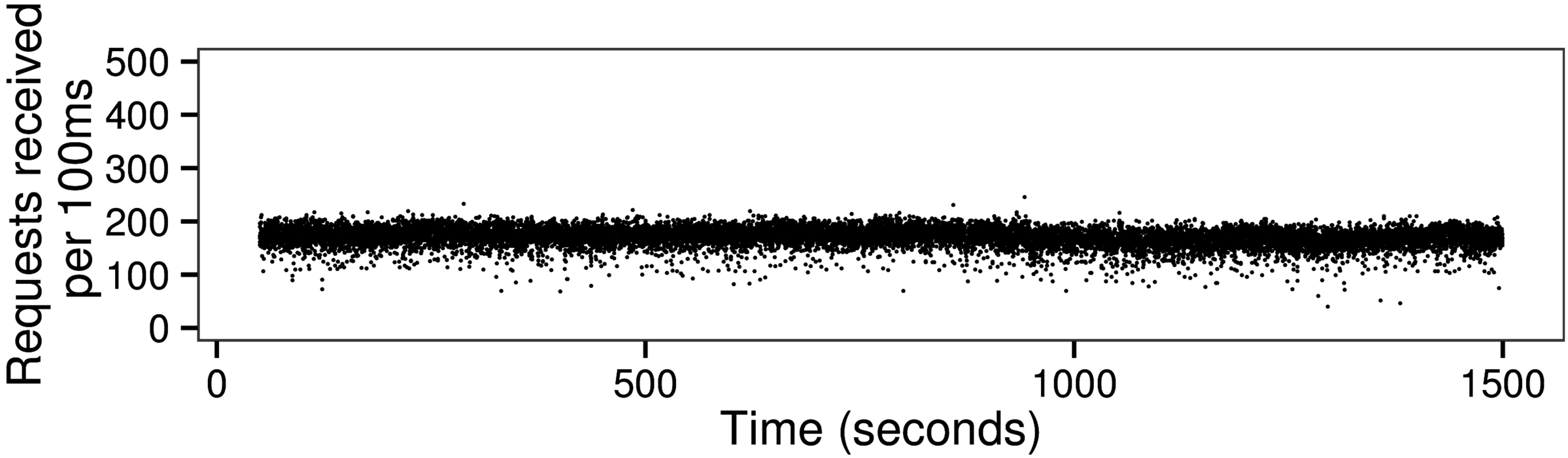


Cassandra Load Profile



Also observed that
99.9th percentile latency ~ 10x median latency

Load Conditioning in our Approach



C3

Adaptive replica selection mechanism that is robust to service time heterogeinity

C3

- Replica Ranking
- Distributed Rate Control

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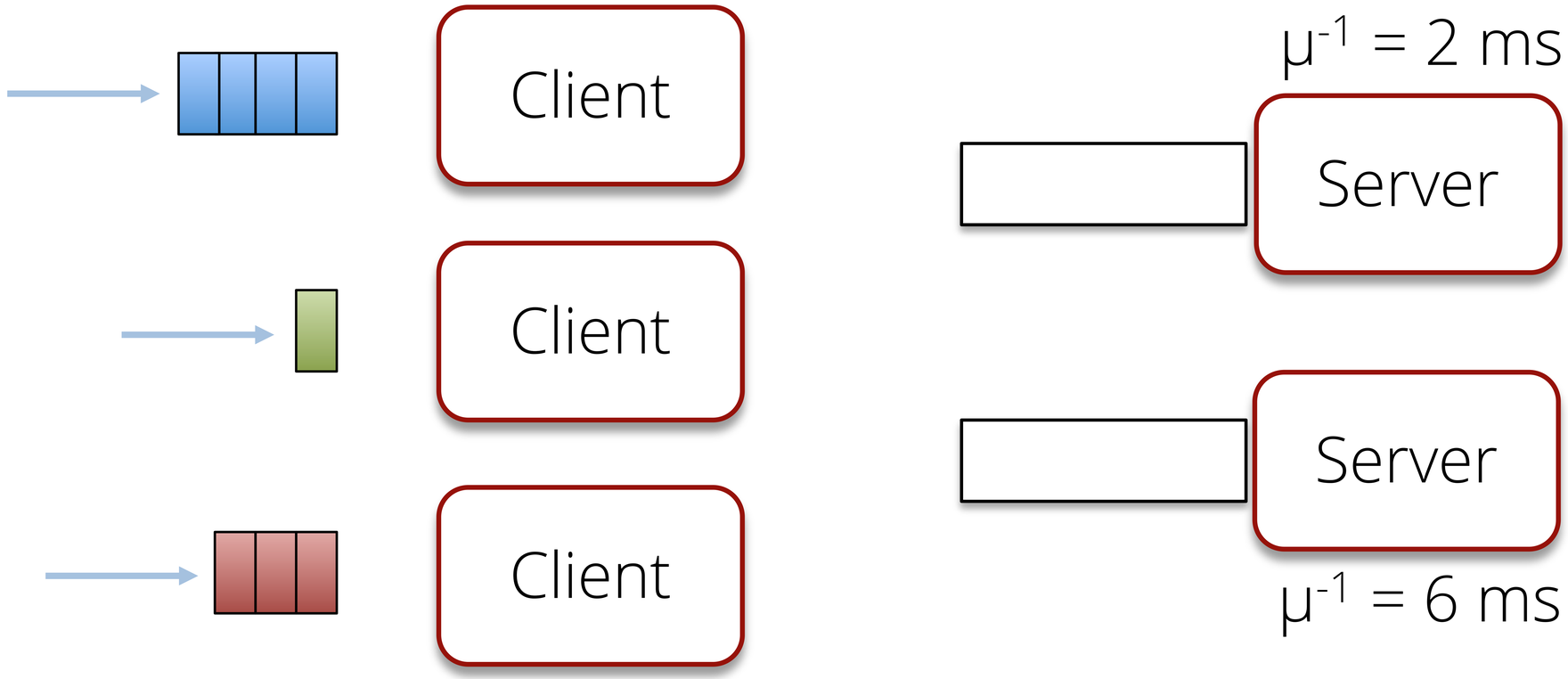
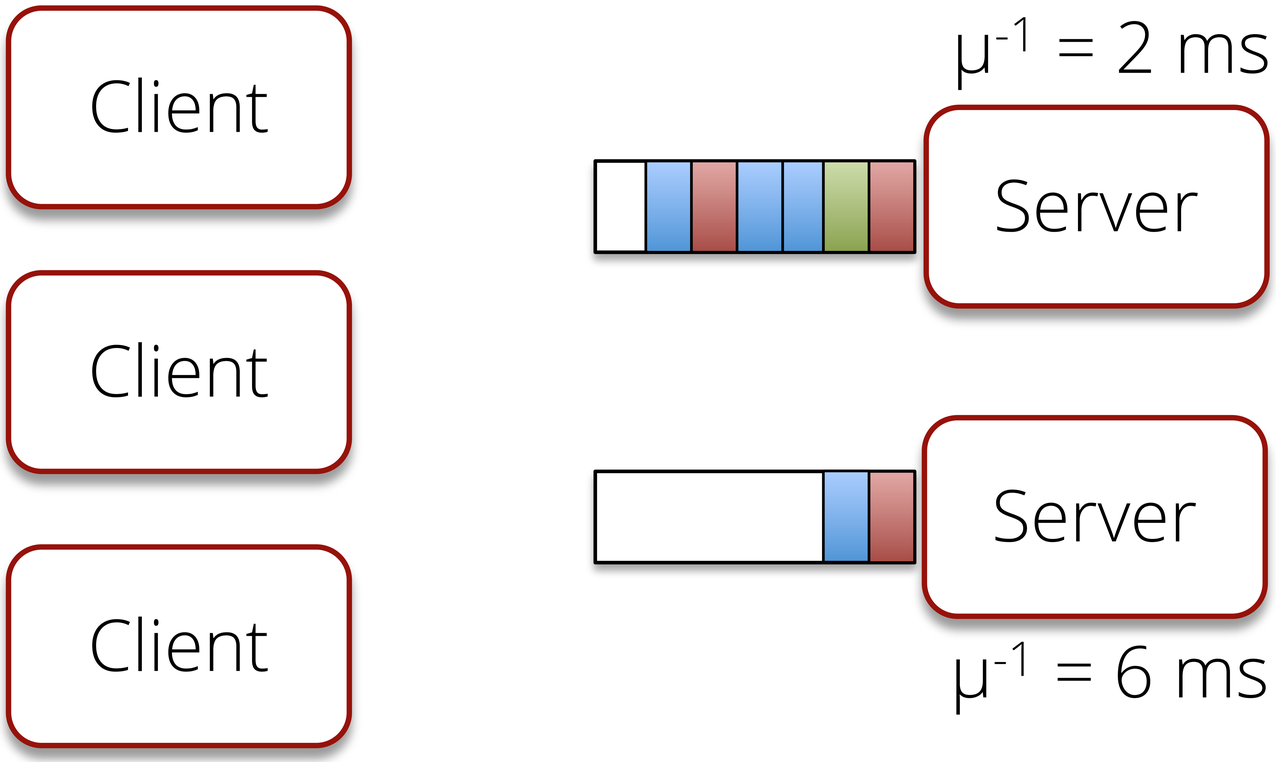

Client
Client
Client
μ^{-1} = 2 ms
Server
Server
μ^{-1} = 6 ms

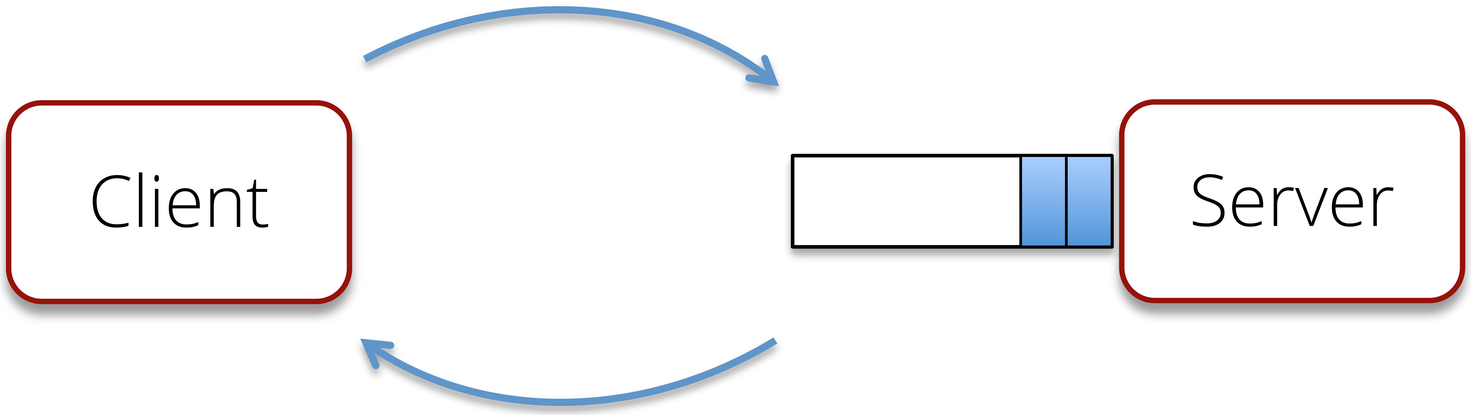


Balance product of queue-size and service time

$\{ q \cdot \mu^{-1} \}$

Server-side Feedback

Servers piggyback $\{q_s\}$ and $\{\mu_s^{-1}\}$ in every response



$\{ q_s , \mu_s^{-1} \}$

Server-side Feedback

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- Concurrency compensation

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- Concurrency compensation

$$\hat{q}_s = 1 + os_s.w + q_s$$

Outstanding requests Feedback

Select server
with min $\hat{q}_s \,.\, \mu_s^{-1}$?

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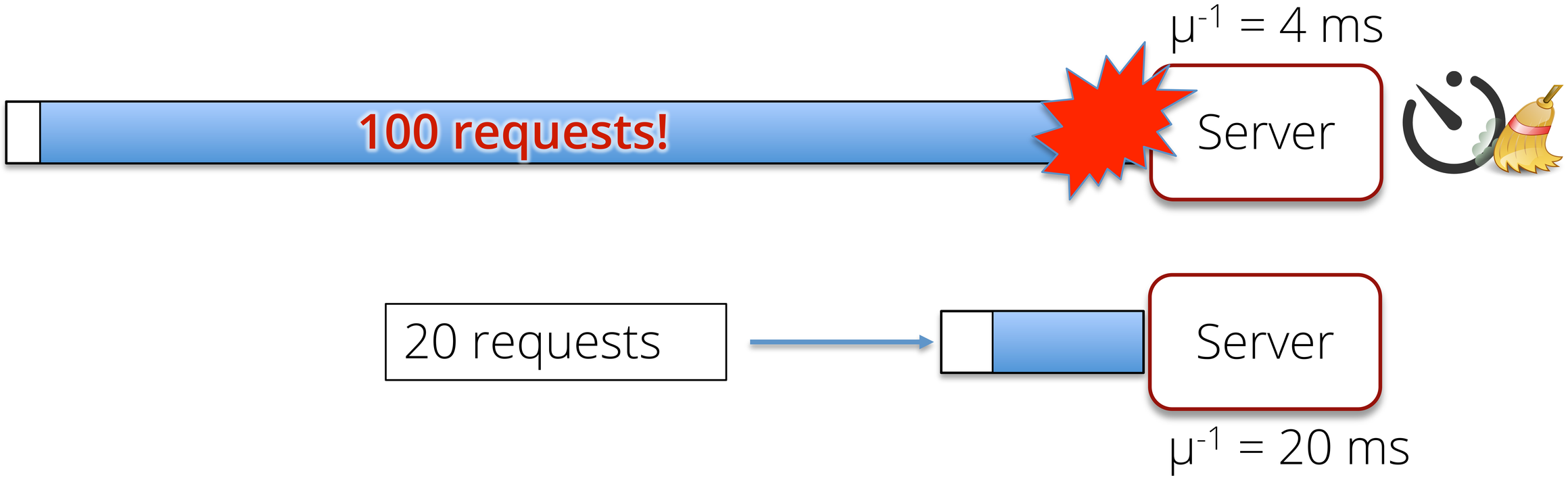
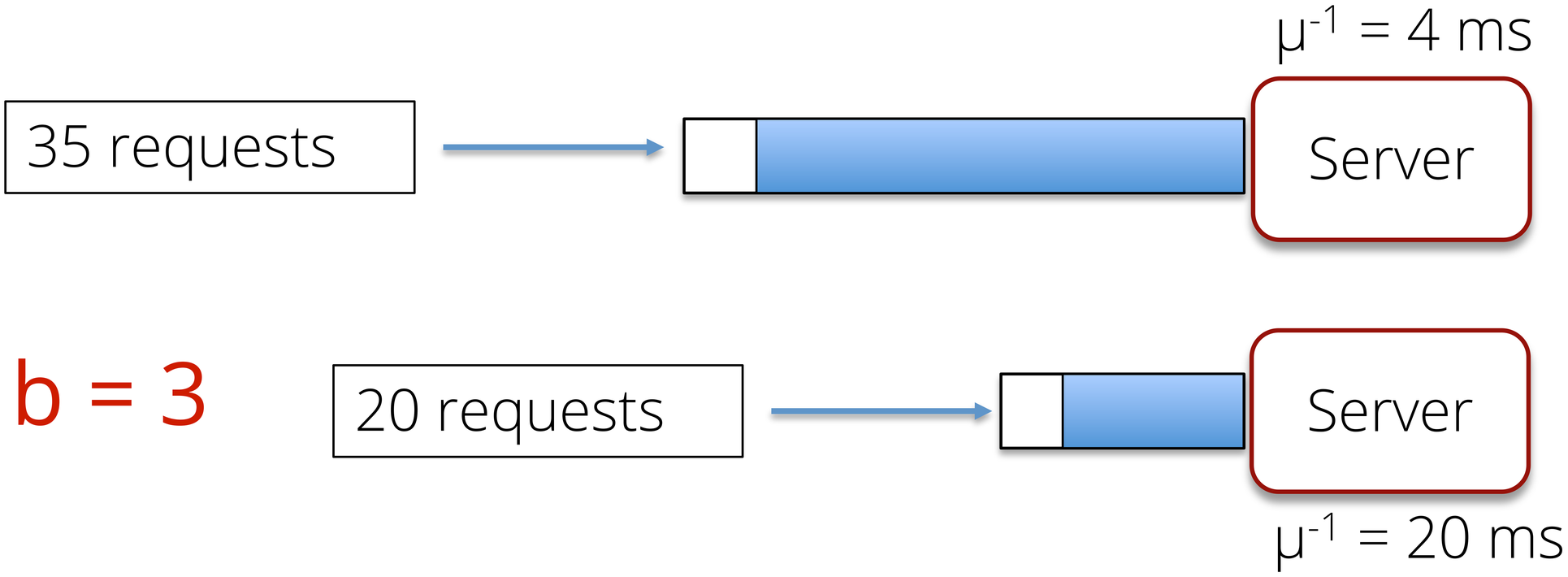
- Potentially long queue sizes
- What if a GC pause happens?



Penalizing Long Queues

Select server with min $(\hat{q}_s)^{\mathbf{b}} . \mu_s^{-1}$



C3

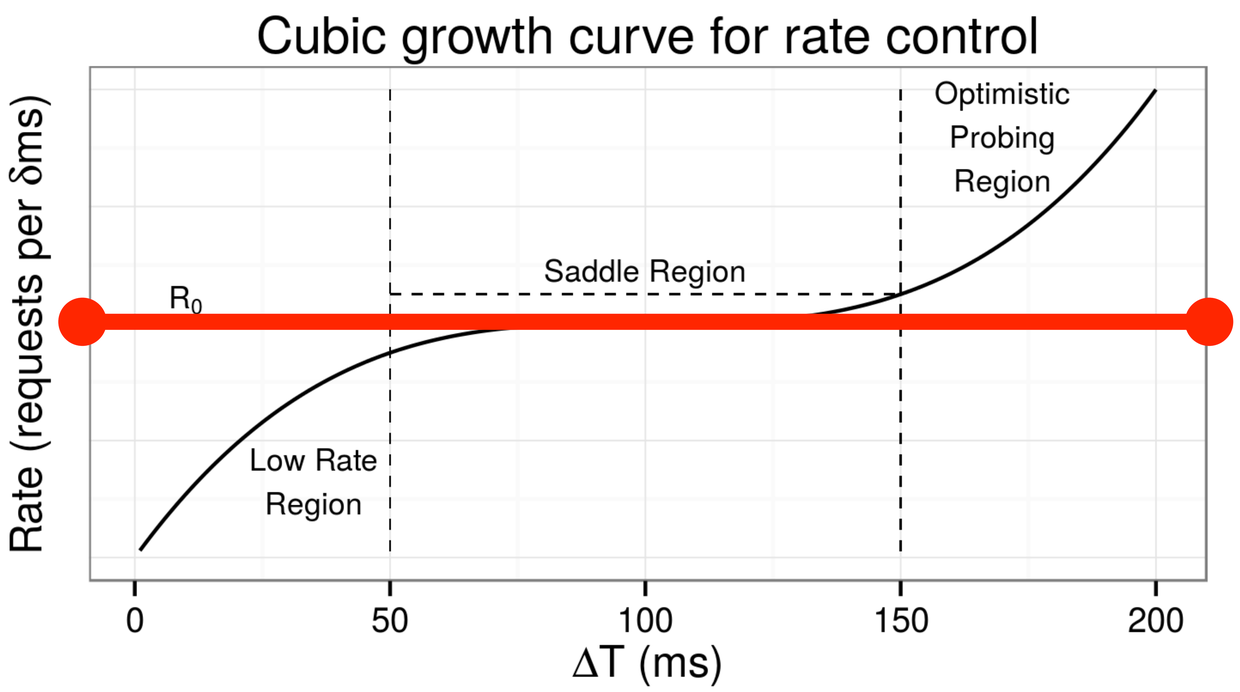
- Replica Ranking
- Distributed Rate Control

Need for rate control

Replica ranking insufficient

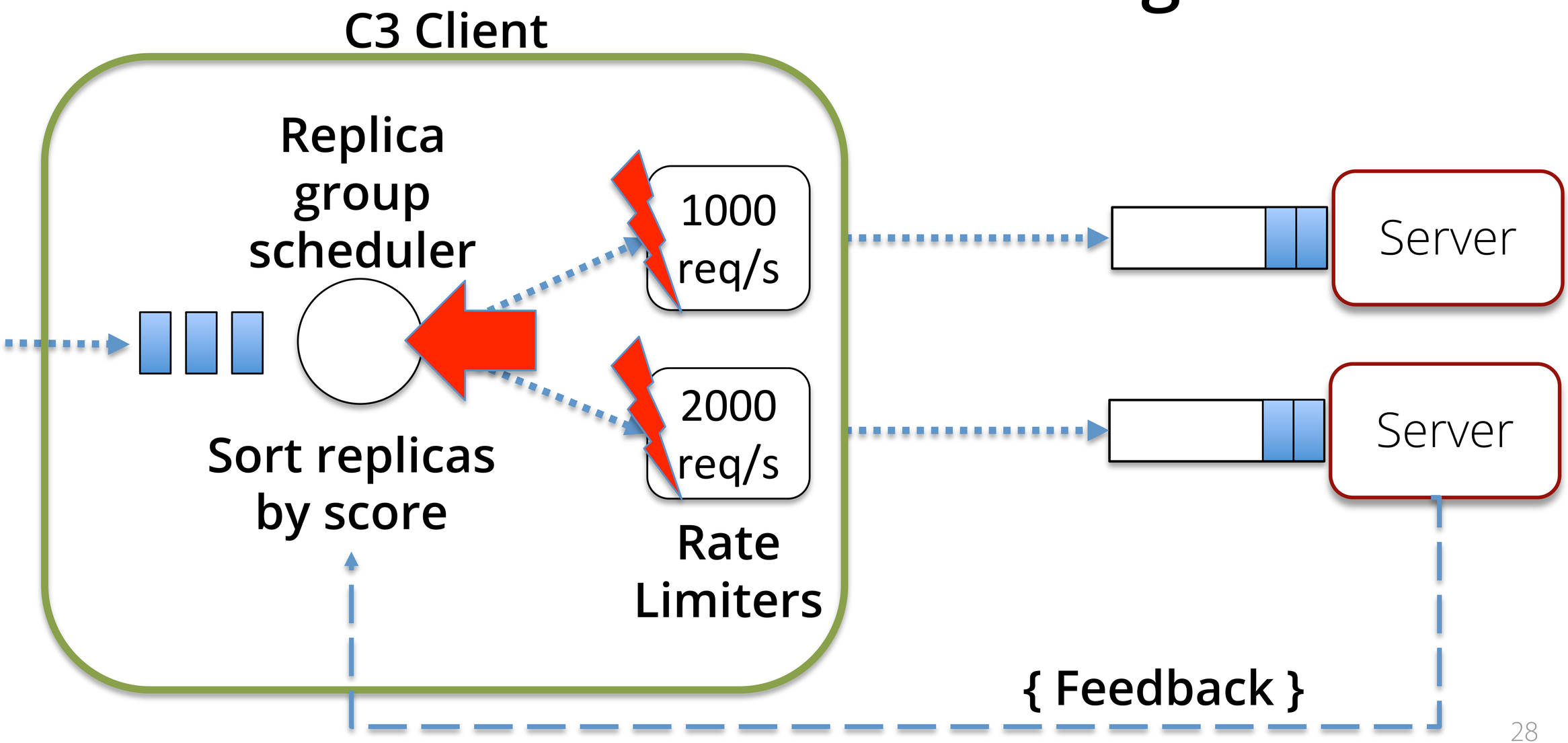
- Avoid saturating individual servers?
- Non-internal sources of performance fluctuations?

Cubic Rate Control



- Clients adjust sending rates according to cubic function
- If receive rate isn't increasing further, multiplicatively decrease

Putting everything together



Implementation in Cassandra

Details in the paper!

Evaluation

Amazon EC2

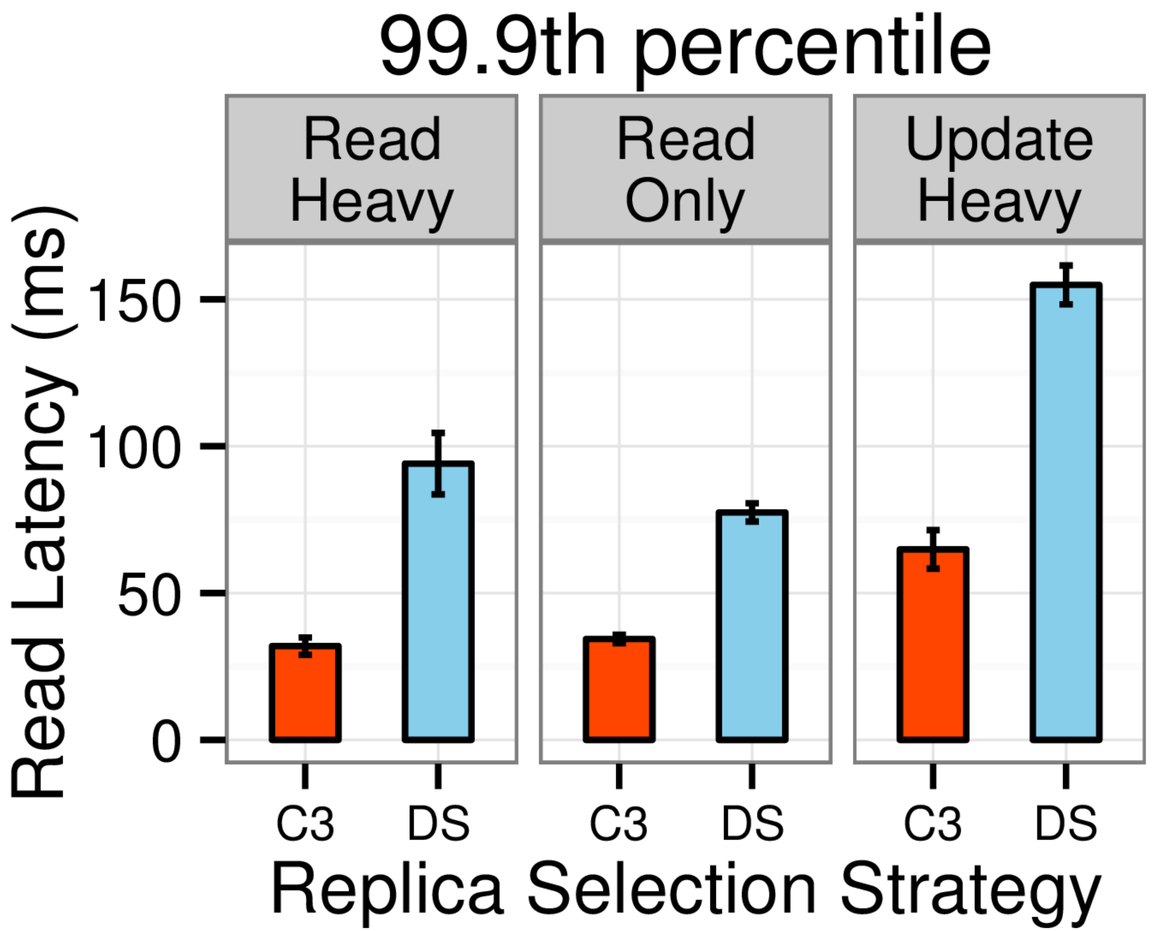
Controlled Testbed

Simulations

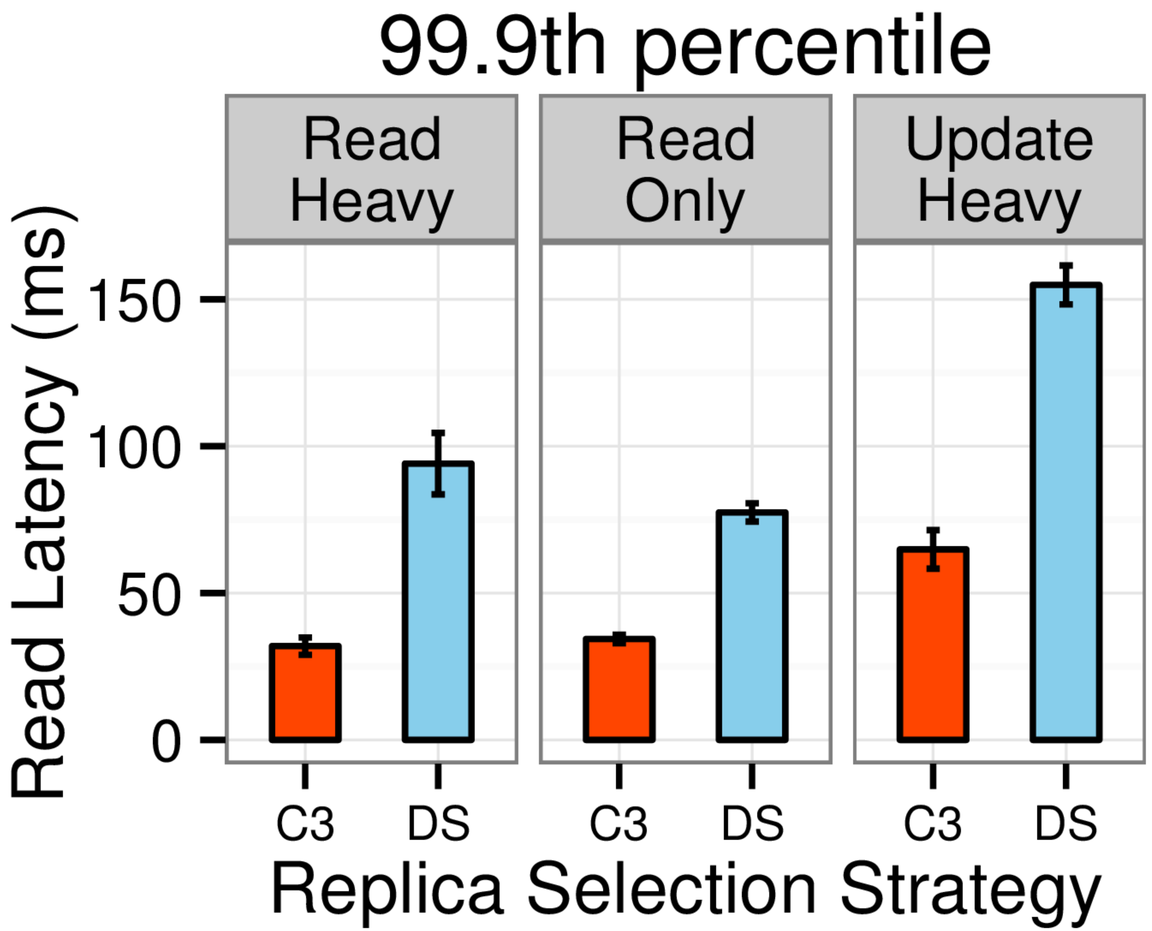
Evaluation

Amazon EC2

- 15 node Cassandra cluster
- M1.xlarge
- Workloads generated using YCSB (120 threads)
- Read-heavy, update-heavy, read-only
- 500M 1KB records dataset (larger than memory)
- Compare against Cassandra's Dynamic Snitching (DS)

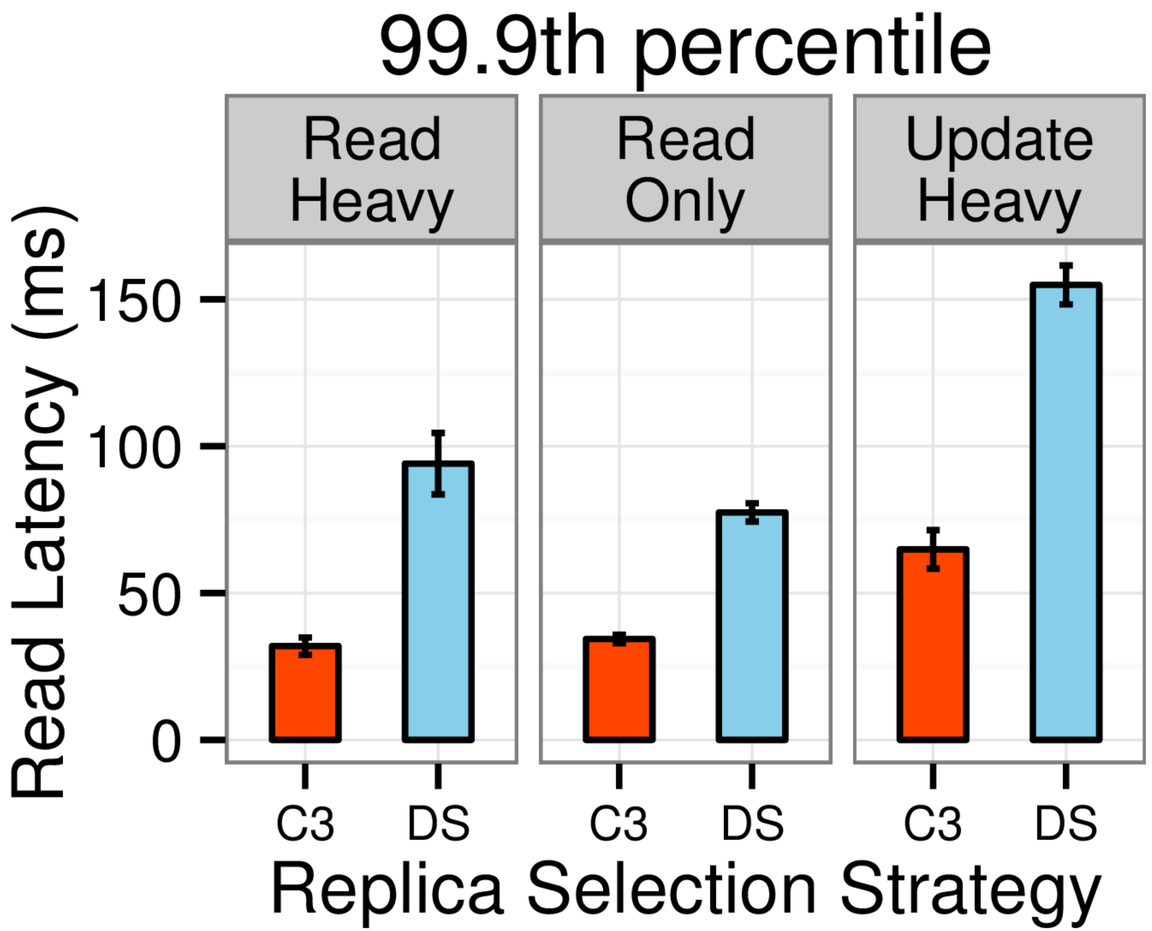


Lower is better



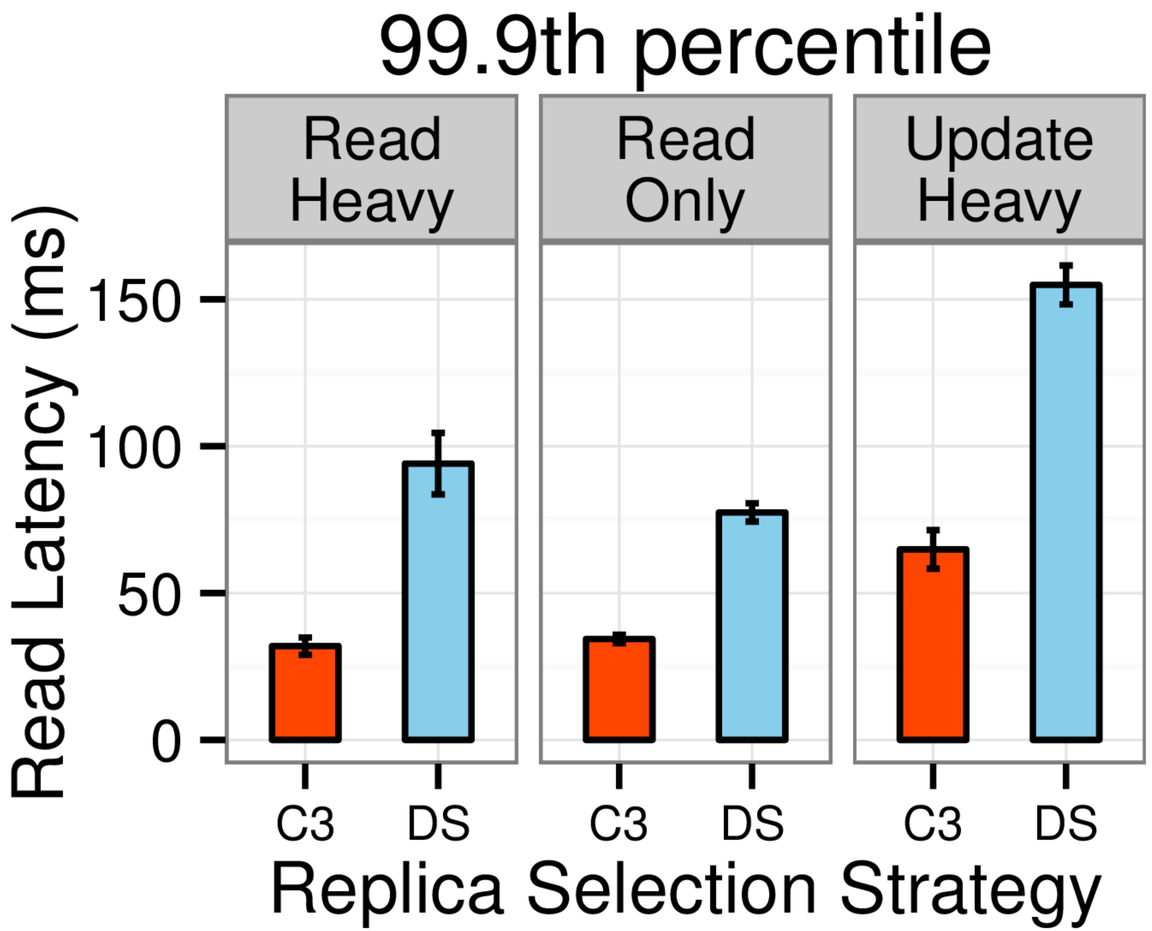
2x – 3x improved 99.9 percentile latencies

Also improves median and mean latencies



2x – 3x improved 99.9 percentile latencies

26% - 43% improved throughput



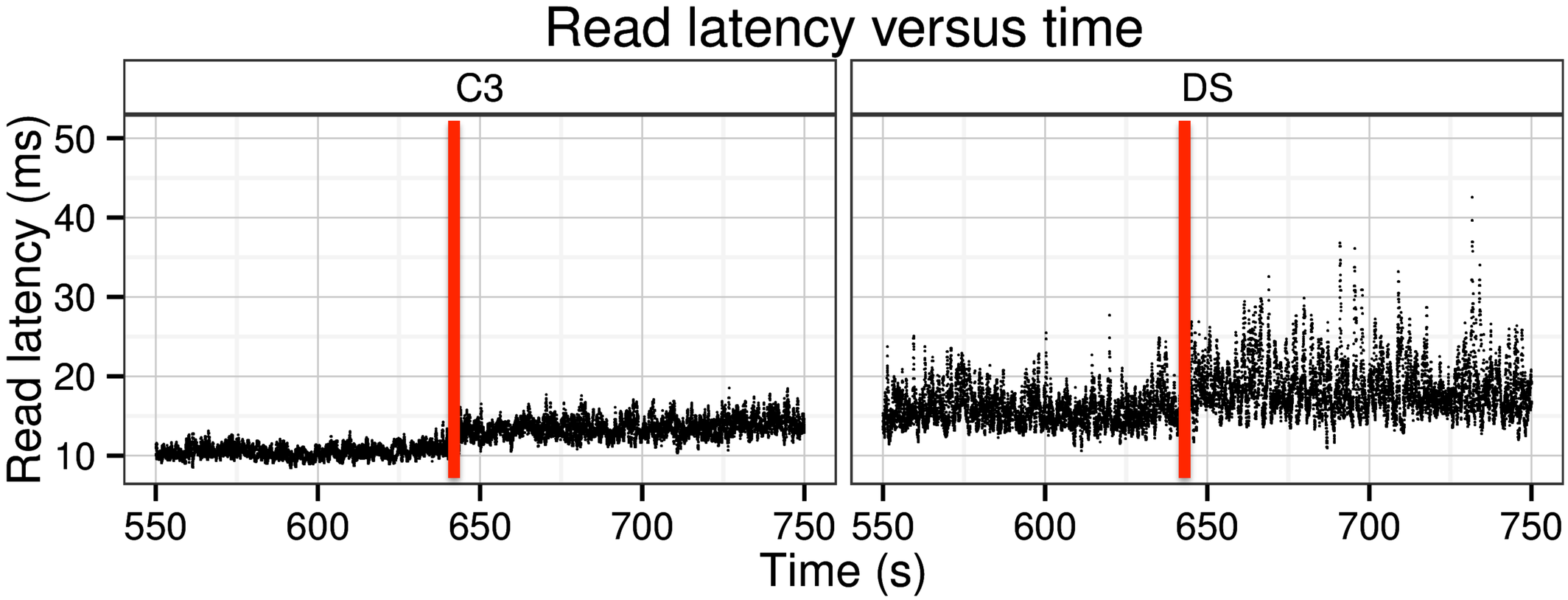
Takeaway:

C3 does not tradeoff throughput for latency

How does C3 react to dynamic workload changes?

- Begin with 80 read-heavy workload generators
- 40 update-heavy generators join the system after 640s
- Observe latency profile with and without C3

Latency profile degrades gracefully with C3



Takeaway: C3 reacts effectively to dynamic workloads

Summary of other results

Higher system load

Skewed record sizes

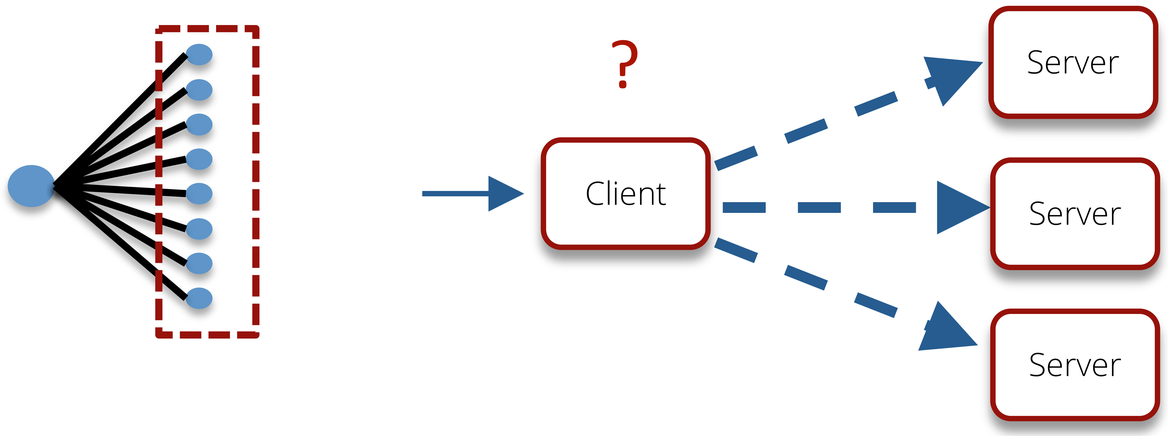
SSDs instead of HDDs

> 3x better 99.9th percentile latency

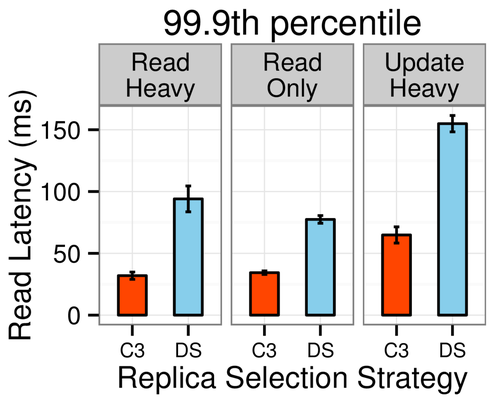
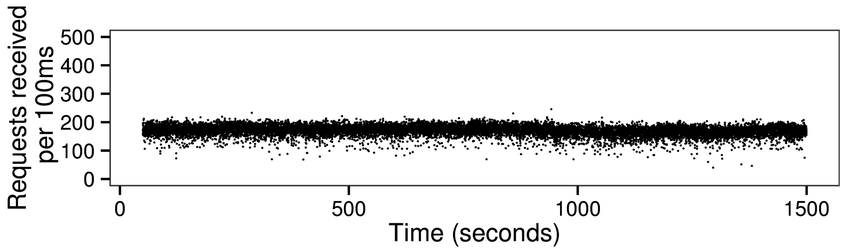
50% higher throughput than with DS

Ongoing work

- Tests at SoundCloud and Spotify
- Stability analysis of C3
- Alternative rate adaptation algorithms
- Token aware Cassandra clients



Summary

C3

Replica Ranking
+
Dist. Rate Control